Chromoacoustics: The Science of Sound and Color

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Go directly to the text of the paper.

Abstract

The purpose of this presentation is to share findings from a decades-long search to develop the optimal method, with some basis in natural law, for translating music—and perhaps *all* auditory manifestations—into chromatic visual displays, a process this paper names *Chromoacoustics*, ("CAS") or "color and sound." The outcome could provide insights into the operation of well-concealed natural laws. It is clear that this research could furnish beneficial results through instructional and therapeutic applications, among which are means to provide enhanced tools for teaching the hearing-impaired.

Chromoacoustique : La Science du son et de la couleur

John S. Sultzbaugh, Ph.D.

Résumé

Le but de cette présentation est de partager les conclusions issues d'une recherche de dizaines d'années visant à développer la méthode optimale, avec une certaine base avec les lois naturelles, pour traduite la musique – et peut être toutes les manifestations auditives – en des affichages visuels chromatiques, un procédé que cet article appelle *Chromoacoustique*, (« CAS ») ou « couleur-son ». Le résultat pourrait donner un aperçu de l'opération de lois naturelles qui sont bien dissimulées. Ceci a été accompli car il est clair que l'issue pourrait générer des résultats bénéfiques à travers des applications pédagogiques et thérapeutiques, procurant des outils pour l'enseignement chez les malentendants.

Cromo acústica: La ciencia del sonido y del color

Por John S. Sultzbaugh, Ph.D.

Resumen

El propósito de esta presentación es el de compartir descubrimientos aportados por décadas de búsqueda para desarrollar un método optimo, con algunas bases en la ley natural, para la traducción de música y quizás toda manifestación en el auditor, para una exhibición cromática visual, un proceso el cual este documento lo nombra como Cromo acústica, o "color del sonido." El resultado puede proveer mejores detalles acerca de la operación de leyes naturales que se encuentran bien ocultas. Esto se ha llevado a cabo porque claramente denota que puede aportar resultados benéficos através de aplicaciones instructivas y terapéuticas, las cuales son destinadas a proveer mejores herramientas para la educación de los seres humanos incapacitados que no pueden escuchar.

Cromoacústica: A ciência do som e da cor
Por John S. Sultzbaugh, Ph.D.

Resumo

O propósito deste trabalho é de compartilhar os descobrimentos de uma pesquisa que levou décadas para desenvolver o melhor método para traduzir música – e talvez todas as manifestações auditivas – alguns baseados em leis naturais, em 'exposição visual cromática', um processo chamado aqui de "Cromoacústica" ("CAS") ou "cor-som". O resultado poderia dar uma idéia sobre o funcionamento de algumas leis naturais e também poderia fornecer resultados benéficos através de instrução e de aplicações terapêuticas.

Farbenklang: Die Wissenschaft des Tones und der Farbe

John S. Sultzbaugh, Ph.D.

Zusammenfassung

Dieses Referat hat den Zweck, nach einer jahrzehntelangen Suche, mit Beruecksichtigung von gewissen Naturgesetzen, eine optimale Methode zu entwickeln zum Uebertragen von Musik, und vielleicht allen akustischen Manifestationen, in optisch-chromatische Darstellungen. Das vorliegende Schriftstueck nennt diesen Prozess ***Chromoacoustics.*** (CAS) oder "Farbenklang". Das Resultat koennte Einsicht in verborgene Naturgesetze vermitteln. Es erscheint klar, dass sich hier eine Gelegenheit fuer instruktionale und therapeutische Anwendungen zeigt. Zum Beispiel, im Umgang mit Hoehr-Behinderten.

Chromoacoustics: The Science of Sound and Color

John S. Sultzbaugh, Ph.D.

Introduction:

The purpose of this presentation is to share findings from a decades-long search to develop the optimal method, with some basis in natural law, for translating music—and perhaps *all* auditory manifestations—into chromatic visual displays, a process this paper names *Chromoacoustics*, ("CAS") or "color and sound." This project was greatly inspired by the Luxatone, a color-organ invented by H. Spencer Lewis and first demonstrated in New York City in February 1916, and by his descriptive article bearing the same name (see Appendix E).[1] Another impetus for the project issues from an instinctual empathy for a favorite composer, Ludwig van Beethoven, who probably never heard many of his own most splendid works.

Just as CAS was inspired by the Luxatone, H. Spencer Lewis was inspired by the thoughts of Aristotle (384-322 BCE),[2] which are preserved in the Greek philosopher's treatise, *De Sensu,* or *The Senses and the Sensible*, Aristotle notes that:

"… we may regard these colors (*viz.* all those colors based on numerical ratios) as analogous to the sounds that enter into music, and suppose that those involving simple numerical ratios, like the concords [the harmonious blends] in music, may be those generally regarded as most agreeable ….”[3]

Not only does Aristotle suggest a correspondence between sound and color, but also that this correspondence is based upon mathematical relationships. It appears from the preceding that Aristotle had some notion of harmony and the overtone series. In “The Story of the Luxatone,” H. Spencer Lewis mentions a number of luminaries beside Aristotle, including Johannes Kepler, Sir Isaac Newton, Louis Bertrand Castel, A.Wallace Rimington, and Sir Hubert von Herkomer, among others, who to some degree recognized a connection, however implicit, between color and sound.[4] L. B. Castel, a Jesuit mathematician, also published a book, *La Musique En Couleurs* (*Music in Colors)* in 1720, in which he described an invention—the “*Couleur-Clavessin,*” or color-klavier, in which he strove to demonstrate the connection between audible and visible frequencies.[5]

Yet it is H. Spencer Lewis’s reference to Albert Abraham Michelson that most keenly aroused interest. In 1907, Prof. Michelson became the first American citizen to win the Nobel Prize (in this instance, in physics) for having devised the means for the accurate calculation of the speed of light, and he later contributed materially to establishing the modern metric system.[6] In 1902, he published a book entitled *Light Waves and their Uses.*[7] Here he reveals what was arguably his intuitive appreciation of an inherent link between audible and visual frequencies:

“… If a poet could at the same time be a physicist, he might convey to others the pleasure, the satisfaction, almost the reverence which the subject inspires. The aesthetic side of the subject is, I confess, by no means the least attractive to me. Especially is its fascination felt in the branch which deals with light, and I hope the day may be near when a Ruskin[8] will be found equal to the description of the beauties of coloring, the exquisite gradations of light and shade, and the intricate wonders of symmetrical forms and combinations of forms which are encountered at every turn.

“… Indeed, so strongly do these color phenomena appeal to me that I venture to predict that in the not very distant future there may be a color art analogous to the art of sound—a color music [underscoring added], in which the performer, seated before a literally chromatic scale, can play the colors of the spectrum in any succession or combination, flashing on a screen all possible graduations of color, simultaneously or in any other desired succession, producing at will the most delicate and subtle modulations of light and color, or the most gorgeous and startling contrasts and color chords! It seems to me that we have here at least as great a possibility of rendering all the fancies, moods and emotions of the human mind as in the older art.”[9]

Although Michelson does not elaborate upon what is meant by “the older art,” viable inferences might include the long-separated visual and audible realms. It might even be inferred by his very use of the term “older” that he views his prediction of the “newer” art as the inevitable synthesis of the two.

The Brain Connection—Mozart Effect and Synesthesia

CAS may shed additional light upon the validity of the so-called "Mozart Effect." In 1993, researchers from the University of California presented evidence that undergraduates raised their spatial-temporal intelligence scores after 10 minutes of listening to a recording of W.A. Mozart's *Sonata for Two Pianos in D-Major*, K. 448. The temporal lobe of the brain processes auditory or sound-related information; spatial-temporal pertains to one's mental ability to manipulate imaginary objects in three-dimensional space.[10] The findings have attracted their fair share of attention, support, and criticism. Because tangible results can be measured in at least some instances, proponents note that the findings are significant.

Others, however, have pointed out that the repeated experiments do not always replicate the expected result, and that the results can depend on variables such as the testing conditions and the experimenters' choices in subjects. Replication (or lack thereof) has generally been a challenge in this type of research because of variations among test subjects and because of factors not yet well understood. One of these factors involved in the success/non-success of these studies may be "locale conditioning" or "charged space" that has been the subject of outside research. This phenomenon, if true, is relevant to Rosicrucian teachings.[11] It is suggested that CAS might very well shed additional light on the topic and possibly even contribute to more productive outcomes in terms of IQ scores.

Another area in which CAS might provide useful information is that of the condition known as *synesthesia*. Some may infer from the term "condition" that this is a medical disorder of sorts, although this is definitely not my opinion, nor do I detect from my inquiries that any such notion is widely accepted. Synesthesia is a union or blending of the senses in such a way that odors might be perceived audibly, visual images perceived tactilely, or—and of particular interest here—sounds perceived visually, especially as colors.

This condition, or perhaps more appropriately, this capability, is said to arise from the limbic region of the human brain, which is responsible for our emotional experiences and responses. The use of visual terms, such as "color" and the "chromatic scale" in describing music, suggests that somewhere in the development of this prehistoric art, musicians began connecting what they produced with the components of the visible-light spectrum.[12] Often *synesthetes*, persons displaying this condition, also display *chromasthesia* as well; that is, such abstractions as letters and numbers are perceived in specific colors.[13]

Moreover, chromasthetes, who have these experiences, might also perceive numbers as having textures and even personalities, aside from symbolic importance. Such awareness might help explain some seemingly irrational notions espoused by some of history's preeminent rational thinkers, as we shall discover. Further research by medical professionals will be of considerable assistance in continuing the investigations here.

A third possible application of CAS is to guide perception, for example, as visual art does. One artist's use of the relationships between colors is so powerful, and can so enhance the viewer's appreciation of the composition's subliminal messages, that it deserves attention here. Vincent van Gogh's life may be considered "colorful" in more than one respect, but it is in its most literal application of this adjective that his impact can be understood. Van Gogh's work gives us the opportunity to experience one of nature's simplest and yet most compelling sensuous secrets: the force of complementary (aka "negative") colors.

It also hints at just how much more perceptive are our minds than we might suppose. The production of complementary colors is so simple and so familiar that elementary school and even preschool students might discover it on their own. The three primary color pigments are red, blue, and yellow; each has as its complement the combination of the remaining two: for red, blue combines with yellow to produce green; for blue, red and yellow produce orange; and for yellow, red and blue produce purple. If one chooses to develop artistic capabilities, s/he will recognize that the plural forms…reds, blues and yellows…are more appropriate labels.

Van Gogh describes how he empowers his compositions and infuses them with his personal signature:

"To exaggerate the fairness of hair, I come even to orange tones, chromes and pale yellow...I make a plain background of the richest, intensest [*sic*] blue that I can contrive, and by this simple combination of the bright head against the rich blue background, I get a mysterious effect, like a star in the depths of an azure sky."[14]

Any significance of the preceding for CAS may seem to have been lost in a graphic arts lesson, however, in fact, Van Gogh underscores how marvelous our perception of what is suggested, purely through the use of pigments, truly is. He is one of many artists whose talents include guiding or "coaxing" our minds into perceiving powerful images that are not immediately obvious at a casual glance. Today's computer technology can guide the human mind in much the same way, coaxing from it perceptions of items or events which, in strictly material terms, are not there or are not happening.

As noted above, the relationship of complementary colors is simple to understand; the physics of light absorption and reflection (optics) can probe its complex mathematical underpinnings, and neuro-biophysics can explain the material basis for its detection, but that relationship can be explored without knowledge of those disciplines.

Our ability to perceive—and clearly—what is not physically present can be experienced in "Lilac Chaser," one of the many examples of remarkable optical effects provided by Prof. Michael Bach, Ph.D., a neuro-biophysicist (and student of musicology) who directs the Freiburg University Eye Clinic in Freiburg, Germany.[15]

"Lilac Chaser allows us to encounter what is technically known as "negative retinal afterimage,"[16] the perception of an image at a location where the image recently appeared but has since vanished. A remarkable aspect of this experience is that the image is perceived, and quite clearly, as its negative—its complementary—color (for lilac, it is a shade of green).

How negatives function in black and white photography can be readily explained: light acts upon photo-sensitive paper by causing it to become darkened through a chemical process. The more intense the light is, the darker the paper will become, but the regions shielded to some extent from that intensity will, to the same extent, remain lighter. The role of complementary colors as "negative" colors is, however, not so easily explained; neither, for that matter, is the manner by which our minds translate the absence of a given hue as its complement. *That* it happens is, however, beyond question. Yet, what might well be the most extraordinary part of Bach's "lilac-chasing" is that not only are we guided to seeing something which is not physically present, but also that our eyes are prevented, without material shielding, from seeing items that *are* present. This is an example of subjective experiences, the realm of non-consensus reality.[17]

The objectives of CAS certainly do *not* include confusing or deceiving its observers. Its objectives rather include employing modern technology to guide—to coax—one's mind into experiencing its greater, and as yet largely unexplored, abilities to perceive, and these abilities can be astounding. Optical bio-physicists can probe phenomena's complex mathematical underpinnings, and neuro-biophysicists can explain the material basis for its detection; but that relationship is something in which one's mind requires no in-depth instruction in order perceive it. Instead, it needs only to remain purely focused upon the topic so that information can be transmitted to the observer's mind—with extraordinary results.

Art and Mathematics

The preceding discussion suggests several instances in which CAS might form the basis for research in applied science sometime in the future. A proper medium for presenting natural laws is the manner in which all phenomena have been expressed well before the dawn of written history: as an art form. Science may hold a treasured position in the collective opinion of humanity because its innumerable applications have done much to raise our overall standard of living, and the longevity required for enjoying its benefits. But certain intangibles, particularly self-expression and the means for delivering it, have proven to be essential to our mental and emotional evolution.

Furthermore, while mathematics—that which is usually viewed as the purest form and language of science—is the basis for the proposed visual co-expression of music, scientific study first requires something to be observed, and the art form proposed should supply ample substance for observation. This is the realm of "non-consensus reality." It is further noted that even though science and mathematics are more consensus-based than other disciplines, at some level they, too, are based on axioms and postulates that are beyond deductive proof and that are provisionally accepted "on faith."

The concept of mathematics-as-art has already provided classroom teachers with a means to render math in a less abstract form, through the construction of tessellations. A tessellation is a visual composition created by drawing a given shape repeatedly to cover a plane—such as a sheet of paper—without allowing gaps or overlaps to occur. The composition is then colored to suit the composer's—the student's—own tastes.[18] Although the skill levels involved are considerably different, tessellations are in some respects a highly elementary version of the gorgeous mandalas, reverential geometric artworks with roots in Hindu and Buddhist (especially Tibetan) traditions. Mandalas are strikingly colorful depictions of the universe, and Tibetan monks fashion them with painstaking care on scrolls or consecrated ground—and in the latter instance, the compositions are erased at the conclusion of sacred rituals. While they are rich in devotional symbolism, and beyond the scope this presentation, there are two aspects which give them significance regarding CAS.[19] Scholars of religion and culture might also make a case for other architecture and other art connections as well—for example, Islamic traditions.

First of all, mandalas begin with a dimensionless point and evolve in all directions into items of awesome beauty. This comports very nicely with one of CAS's aspects: to add dimensions to music in order to enhance the (often casual) listeners' enjoyment and appreciation of the composition.

Secondly, each color used to create a mandala has its own pertinent and dynamic meaning. Each begins as an element of delusion that is transformed into a seed of wisdom. What each represents is, however, less relevant to CAS than the simple matter that it *has* relevance. To consider that colors have meanings beyond their aesthetic values is a fundamental premise of the project.

The unfolding of sublime importance from a central point is a motif that—perhaps unexpectedly—may be found in the iconography of Eastern Orthodox and Byzantine Catholic religious traditions. One such example, glorifying the Theotokos (Virgin Mary), depicts her and the Christ child, literally surrounded by residents of Heaven and Earth—much as the planets of our solar system surround the Sun.[20] This is clearly part of the mandala tradition, though in a Christian manifestation. The theology of icons in general was established by the Seventh Ecumenical Council (Nicaea II), which met in 787. The decrees of this council reveal a distinct similarity with the Mandala Tradition, in particular,

"As the sacred and life-giving cross is everywhere set up as a symbol, so also should the images of Jesus Christ, the Virgin Mary, the holy angels, as well as those of the saints and other pious and holy [persons] be embodied in the manufacture of sacred vessels, tapestries, vestments, etc., and exhibited on the walls of churches, in the homes, and in all conspicuous places, by the roadside and everywhere, to be revered by all who might see them. For the more they are contemplated, the more they move to fervent memory of their prototypes. Therefore, it is proper to accord to them a fervent and reverent adoration, not, however, the veritable worship which, according to our faith, belongs to the Divine Being alone—for the honor accorded to the image passes over to its prototype, and whoever adores the image adores in it the reality of what is there represented."[21]

In all such traditions, the mandala or icon is "symbolic," that is, it is a *mysterion* connecting one level of reality with another, and this connection is real—actually more real than quotidian realities. This accords with the ancient and current practices of those traditions that employ these images.

Sympathetic Vibrations

Resonance as it applies to CAS specifically concerns those frequencies that are *sympathetic vibrations*; these are essentially multiples of a given tone's Hz value.[22] Regarding visible light colors, also known as the visible-light spectrum from deep red to deep violet, frequencies are so great that they are expressed in *terahertz*, 10^{12} or one trillion Hz, also denoted "THz."

Sympathetic vibrations have a special relationship to any pitch created by any means, and as we shall see, resonance can be very pleasing, very irritating, or even downright devastating.[23]

H. Spencer Lewis built a Sympathetic Vibration Harp, which was a simple harp of 12 strings, each one tuned to one of the twelve pitches of the chromatic scale. By striking a tuning fork that vibrated at one of those twelve pitches, an investigator could identify its corresponding frequency on the harp because the string in question would audibly vibrate "in sympathy" with the fork as it passed near the string. This remarkable characteristic could furnish a harmless delight for an interested audience.

The reality and power of sympathetic resonance can be seen in its ability to destroy structures such as bridges and buildings. An example is the Tacoma Narrows Bridge, a suspension bridge, which was opened to the public on July 1, 1940; it was hailed as an example of both elegance and economy in civil engineering. It loomed 425 feet above the Tacoma Narrows, a strait which part of Puget Sound in the state of Washington. Unfortunately, its designers had failed to recognize the impact that aerodynamics—and sympathetic vibration—might have on the structure. Almost as soon as it was opened, the bridge began to undulate in strong breezes, so much so that it earned the nickname, "Galloping Gertie." On November 7, 1940, high winds created a very low (0.2 Hz), but also very destructive pitch and violent (twenty-eight-foot) undulations, undermining the bridge's structural soundness and culminating in "Gertie's" total collapse.[24]

The Luxatone—Visual Representation of Music

In all likelihood, people began to associate color with music almost as soon as they began to produce it. Musicians and musicologists have been using "color" (to describe tonal characteristics), and "chromatic scale" (to identify the collection of half-step pitches between any tonal note and its first octave multiple), for quite a while. These terms allude to a relationship between sound and color, which is in fact a relationship between audible and visible frequencies, respectively.[25]

The *Luxatone*, a color-organ invented by H. Spencer Lewis and first demonstrated in New York City in February 1916, is described in his article bearing the same name.[26] Although the Luxatone was dismantled long ago, it may be studied and understood today through records of its construction and operation. As indicated by the Rosicrucian concept of the Cosmic Keyboard and its accompanying musical keyboard, there is a direct relationship between sound and color, in which the latter is an arithmetic multiple of the former. Musical notes have special relationships with their factors and multiples. Everything on the keyboard is based on its scientifically demonstrable vibratory levels.

The number 24 plays an easily overlooked part in the development of the CAS process; just as the number 12 represents the number of half-tones or half steps in an octave, 24 denotes the number of its quarter-tones. To many traditional Western musicians this might seem to be excessive subdivision, but as we shall see, some modes contain more than 12 notes. Although ¼ tone scales are seemingly of no particular concern in Western musical composition, there may be rare occasions when their appearance is essential; moreover, these scales have an illustrious history all their own.[27] Here the number 24 also provides a practical way to describe factors and multiples, giving that quantity added importance.

The number 24 can be divided evenly by 1, 2, 3, 4, 6, 8 and 12; these seven numbers are 24's factors. Now 24 times 2 is 48, 24 times 3 is 72, and 24 times 4 is 96; these three are just the first of an endless quantity of numbers that are 24's multiples.

H. Spencer Lewis's device intercepted the frequencies from any given sound source, measured it and translated it into its corresponding color.[28] The Luxatone achieved this effect by activating red, green and/or blue colored light bulbs—these hues being the primary colors of the visible-light spectrum. Regarding visible light, red and blue form magenta, blue and green form cyan, and green and red form yellow. When all three primary light colors are combined, the product is white light, appropriately called the *additive* process.[29] (These primary colors differ slightly from those of the pigments used in visual art, where, yellow replaces green, green is produced by mixing equal parts yellow and blue, orange by equal parts of yellow and red, and violet by equal parts of red and blue. Combining the three primary pigments results in black, the absence of all color. For this reason, mixing pigments is known as the *subtractive* process.[30]

The red, green, and blue light bulbs of the Luxatone were contained in a triangular, translucent screen. The intercepted frequencies were measured and translated into the corresponding frequency according to the Keyboard. One may infer from descriptions that the fundamental, or most recognizable pitch of the emitted sound, would instantly be translated into its visible analog, although all sounds consist of a distinguishing set of tones which are part of the overtone series. When a given pitch such as C-256 is sounded by a musical instrument (or other producers of sound, such as the human voice) other pitches, or overtones, influence the *timbre* or tonal quality of the sound emitted.[31]

The pitch most easily recognized by the listener is known as the "fundamental" or "first partial." Simply put, all sound arises from the vibrations of some part of an instrument. In accordance with the Cosmic Keyboard, Middle C is identified as 256 cycles per second (Hz); this is a mere six Hz below the regularly accepted standard.[32] It is also much easier to use as an example. When an instrument sounds "C-256," "C" arises because the instrument is vibrating at 256 Hz. The vibrations activate or "excite" air molecules at the same number of cycles per second, and these air molecules in turn excite others, causing the sound to travel outwards from its source (the instrument) in all directions. The velocity of sound through air molecules at 20^{o}C (68^{o}F) at sea level is 343 meters (1,125 feet) per second,[33] which translates to very nearly 767 miles per hour.

Chromoacoustics

If the fundamental or first partial of a given pitch, such as C-256, were the only pitch being sounded, one could not distinguish between the instrument in question and any other instrument sounding that pitch. But each instrument sounds additional pitches that combine to create the unique timbre of a given instrument. Any instrument sounding C-256 is also sounding at least some of the following: 512 Hz, 768 Hz, 1,024 Hz, 1,280 Hz, 1,536 Hz, 1,792 Hz, 2,048 Hz, 2,304 Hz, and 2,560 Hz.

512 Hz is the first overtone or second partial; it is also 2 x 256 Hz. The second overtone, or third partial, 768 Hz, is simply 3 x 256 Hz. The ninth overtone, or tenth partial, is of course, 2560 Hz, or 10 x 256 Hz.[34] A given instrument can emit greater or higher frequencies, and at least in theory, the overtone series is endless; in fact, the range of human hearing is 16 to 20,000Hz.[35]

The preceding is relevant to CAS because, in essence, "sympathetic vibrations"—discussed above—make up what is known as the "overtone series."[36] The series is essential to establishing harmony in music, and it has another, implicit role in the project. If researchers continue to track the overtones of C-256, they would discover that at a given point, the vibrations are no longer audible. Very high partials of musical notes have the same frequencies as visible light (measured in THz), even though light, unlike sound, does not require a physical medium, to propagate through space and is a transverse vibration, in contrast with the longitudinal vibrations that characterize sound. This occurs at an extremely high frequency, its 2,199,023,255,551st overtone, or 2,199,023,255,552nd partial (!).

In the visible-light spectrum, the frequencies of colors are commonly identified in ranges. The midpoint of a given range may be deemed the "purest" hue of a given color. For example, green's Hz-value occupies the range of 520 to 610 THz.[37] The mean of this range is 565 THz, or 565 trillion Hertz; remarkably, it is also 2,199,023,255,551st overtone of the fundamental. The value 256 Hz is exactly 562,949,953,421,312—or approximately 563 trillion—Hertz. This is very nearly the midpoint of the green range, so Middle C's visible analog is extremely close to "pure" green. And just as Middle C begins the Octave Eight of the Cosmic Keyboard, green begins Octave 49.

Of course, these and all other partials decay or "fade away," and at a more rapid rate than does the fundamental or first partial.[38] CAS does not address this occurrence because the images portrayed in its presentations correspond *only* to the fundamental and overtone frequencies (the partials involved) at the very instance that they are produced. Thus, the objective of CAS is to take a sort of "snapshot," of that instant, and then to preserve the visual analogs as those analogs proceed right and left of the ordinate. The issue of partials' decay is a completely legitimate object for study, but CAS is intended to form a visual picture of the sounds that the observers hear and recall. This is a more tangible visible version of the mental sequencing that allows listeners to link together the notes that create a melody (and "melody" is here used in its broadest application) rather than simply hearing the notes individually and with no memory to connect them. This demonstrates that CAS is an art form rather than a physicist's examination or musician's experience of acoustical phenomena, where the decay-rates of the partials are of greater concern.

It might, however, be possible to consider the effects of the partials' decay, using one of the devised alternative presentations for timbres if the one now proposed proves impractical. This alternate approach is briefly demonstrated in Appendix B.

As described below, the CAS presentation uses the Cartesian coordinate graph, assigning to the ordinate or y-axis each partial, with the higher frequencies' appearing higher on the axis. The abscissa's or x-axis' role is to extend the observer's memory of the overtones sounded. It allows each partial to remain visible for several seconds (optimally, seven seconds), providing the observer the opportunity to view the visible imagery being produced. Such nominatives as "seconds" and "Hertz," representing, respectively, units of time and event per duration, are employed here. They are, of course, artificial constructs for recording data, and they facilitate the dissemination of information among those who understand the designations. This does not, however, suggest that these forms of measurement, of seconds and Hertz units, are absolutely indispensible. If other reliable modes of measurement were to be preferred, these could be substituted for the units employed here. Such substitutions would invalidate neither the information contained in the Cosmic Keyboard, nor the conclusions reached through relying upon it. The abscissa affords the observer extra time to allow him to experience a visual continuity of the notes which he is subconsciously stringing together to recognize as the melody.

To represent dB volume, one can use a frequency analyzer approach. Frequency analyzers have been in use for some time, as H. Spencer Lewis demonstrated with his Luxatone. In 1938, Dr. Carl E. Seashore published *Psychology of Music*, and employed the Henrici Harmonic Analyzer to "dissect" (so to speak) timbres into their partials of the overtone series.[39] Because we tend, in written musical notation as well as with temperatures, to present increases in quantities as increases in elevation, the overtone series would be depicted as follows: varying levels of decibel volume would correspond with varying intensities of each partial's brilliance. The partials of a given timbre, or of given timbres, would issue from what is known in analytical geometry as the "ordinate" or "y-axis," displaying exclusively positive values, and travel both leftwards and rightwards (parallel to the "abscissa" or "x-axis") from ordinate points designating their given Hertz-values.

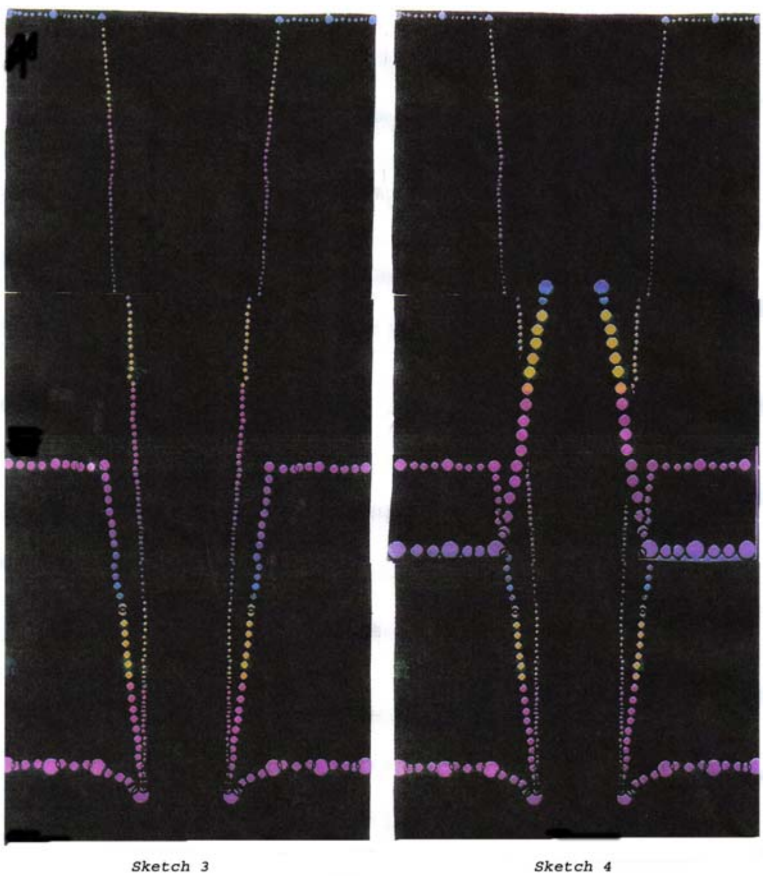

Figure 1

As noted above, the abscissa affords the observer extra time (about seven seconds) to allow the observer to experience a visual continuity of the notes which he/she is subconsciously stringing together to recognize as the melody. Although the best I can do at present is to sketch the effect, metaphorically providing you with a stick figure where a detailed portrait should be, this might still be a helpful starting point. Note that Sketches 3 and 4 in Figure 1 provide a woefully primitive illustration of the field; for 3, the vertical (y) axis would almost "slice through" the "c" in "Sketch;" for 4, it would nearly bisect the "h" in "Sketch.

Although the fundamental pitches might be very different from those depicted in the Cosmic Keyboard, the conversion process would be constant. For the octave of middle C, or C-4, a.k.a., the Cosmic Keyboard's Octave Eight, the corresponding visible frequency (or color) would be the frequency of the fundamental's 2,199,023,255,551st overtone (virtually, "pure" green). The visual presentation would appear simultaneously with the performance of the musical composition; this translation is illustrated below.

But here a problem seems to arise: this process applies only to the scale in which the beginning, or *Tonic***,** pitch is Middle C. After all, the spectrum of visible light is confined to the range of 384 to 769 THz, or trillion Hertz—approximately one octave of vibrations. What about the *many* overtones of C-256 below the visible light spectrum? What is more, what about the overtones for other frequencies of C, ranging from C-16 to C-128, and from C-512 to C-16,384?

Fortunately, both the Cosmic Keyboard and Prof. Michelson's *Light Waves* provide solutions. [Figure 2, right] In the former, the color series repeats itself (Octaves 48 through 50). In *Light Waves* the color series, created by the refraction of light from the surface of soap-bubble film, behaves in the very same way.

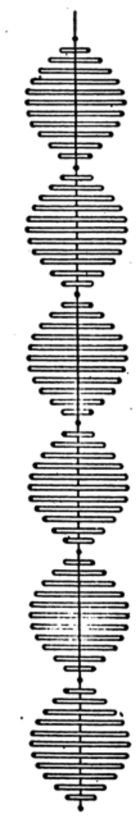

FIG. 3

A primary goal of CAS, particularly as an art form, is to add a visible dimension to an exclusively audible discipline. The position of the visible analog to each of the overtones would be accurately depicted by its position on the ordinate, and its decibel value or volume would be denoted by the corresponding intensity or brightness. Otherwise, however, the hues presented would be identical for the several *audible* pitches of C: 16 Hz, 32 Hz, 64 Hz, 128 Hz, 256 Hz, 512 Hz, 1024 Hz, 2048 Hz, 4096 Hz, 8192 Hz, and 16384 Hz would be represented by the analog for 256 Hz: 562,949,953,421,312—or approximately 563 trillion—Hertz

Figure 2

Some hints on other ways to present color music can be inferred from illustrations by Professor Albert A. Michelson.[40] First of all, he specifically identifies, and illustrates, Lord Kelvin's torsion-driven wave-model [Fig 3 from Michelson, left [41]]. This model demonstrates the light wave's implicit three-dimensional nature, and was developed by Kelvin sixty years before Albert Einstein made his Nobel Prize-winning discovery of the photoelectric effect.[42]

Extra-Scientific Approaches to Investigations

While modern math and physics are most useful in these investigations, as with many human endeavors, there are other approaches as well. As we have seen, science deals in the verifiable (and thus falsifiable). However, there are other dimensions to explorations of these questions. In the realm of the extra-scientific practice of numerology, some interesting parallels are found.

Numerology pertains to something more than either is sometimes assumed in academic settings. As is well known, the study of music, as both an art and the object of scientific deliberation, was of tremendous interest to a most remarkable—and mysterious—figure of history: Pythagoras. Often considered the father of mathematics *and* of music, he was born ca. 575 BCE on Samos, a Mediterranean island near the coastline of Greece. So much of his biography is cloaked in mystery because he seems to have preferred it that way: his studies appear to have brought him to the Mystery Schools of Egypt and Babylon, and at one point he became associated with the Magi of Persia, who were learned individuals probably best known for their presence (as the "Wise Men" or Magi) in the story of Jesus' birth in the Christian scriptures.[43]

Pythagoras organized his own initiatic mystery school, now known as the Pythagoreans, which helps explain why so little is actually known about his broader philosophy and teachings. Incidentally, these include the belief in soul transmigration—in reincarnation. But more relevantly here, it could be argued that while he revealed the science that underlies music, he also beheld and treasured the *art* of mathematics. It is tempting to provide at least a partial list of the Pythagoreans' contributions to mathematics, but even a well-edited collection would begin to obscure the topic of this presentation. Suffice it to say that geometry, or "Earth measurement" was introduced ca. 300 BCE and is primarily attributable to Euclid;[44] trigonometry, or "triangle measurement," was introduced ca. 150 BCE and is primarily attributable to Hipparchus of Bithynia.[45] The Pythagoreans were doubtlessly familiar with the mathematical rules of both disciplines, and yet they *predated* both by more than two centuries. The Pythagoreans also introduced the world to irrational number, very real values that cannot be expressed as the quotient of two integers ("fractions" to most of us), and without which neither geometry nor trigonometry could operate (or even exist).

The Pythagoreans' considerable achievements can be generalized this way: 1) they discovered mathematical principles inherent in nature, and 2) they went on to apply those principles to art. Pythagoras is credited with having employed the arithmetic of acoustical physics to introduce octaves to the art of music. This is noteworthy by itself, but the Pythagoreans went on to uncover simple yet profound geometric laws in the natural world that continue today to exert their influence in the realm of self-expression. Among the topics they contemplated at great lengths were astrology and numerology. It might be helpful to keep in mind that even science, which insists upon following time-tested, reliable study methods, is itself a work in progress; and while the absence of a given experience might justifiably disqualify it from being considered in the rigid discipline of scientists, the absence of an experience is *not* synonymous with the experience of an absence. The Pythagoreans were well-versed in the elements of astronomy and chemistry, as well as mathematics, and they were apparently motivated to seek out paradigm-altering evidence.

Thus even today, as scientists are studying synesthetic phenomena, they are far from concluding what a synesthete's limitations might be. In fact, one recognized synesthete has already noted that to her, numbers not only have corresponding chromatic or color values, but also impress her with traits of personality.[46]

Further historical and cultural researches will be able to assess the scientific value of these extra-scientific data which come to us from other approaches to knowledge.

Relationships between Visible and Audible Frequencies

Returning to the Cosmic Musical Keyboard, the link between audible and visible frequencies begins to present itself at 192 Hz. That frequency or vibratory rate is identified as the note of G, five half steps—known among musicians as a perfect fifth—above C4 or Middle C.[47] Although Middle C can range from 256 to 280 Hz, and the Cosmic Keyboard identifies 256 Hz as the most relevant pitch, while the commonly accepted Hz-value among American musicians appears to be 261.626, or 262, Hz .[48]

One can also note that the color of deep red is identified as the note's "visible analog," so to speak. The frequency of deep red is G-192's 2,199,023,255,551st overtone. (NOTE: The relationship can be applied to what American musicians generally accept as the frequency for the key of G; on the scale below Middle C, that frequency is conventionally recognized again, by American musicians, to be 196 Hz, rather than 192 Hz, as noted in the Cosmic Keyboard.)

The range of human hearing is usually recognized as beginning at 16 Hz and ending at about 20,000, or 20 Kilohertz (KHz), while the visible light spectrum is expressed as factors of 100 Terahertz (THz, or 10^{12} Hertz).[49] Using the pitch of G-196 as an example, there is no *apparent* connection between that pitch and the frequency of 493 THz. In terms of octaves, visible light begins in the 48th Octave of the Cosmic Keyboard, 41 octaves above G-196; G-196's analog in Octave 48 is 431,008,558,088,192 Hz, or about 431 THz, which is unquestionably deep red in the visible-light spectrum. It is, of course, also G-196's 2,199,023,255,551st overtone, or 2,199,023,255,552nd partial. The accepted pitch for G directly below Middle C (192 or 196 Hz) is not an issue; neither is the fact that the visible-light "scale," so to speak, begins at G rather than C. The salient point is that every possible audible pitch has an arithmetic analog or counterpart in the visible light spectrum.

Next Steps

Understanding the preceding is quite important, and yet it brings us only to the starting point for our journey to translate music—and all audible frequencies—into a visible art form. One could develop a variety of visual presentations based upon the arithmetic link between audible and visible frequencies, and consider the simplest type, although it might not be at all simple with respect to its foundation. Those whose interests include visual art, music, and computer programming are not only invited to participate in contemplating the optimal type of presentation, but they could prove indispensable in developing it.

As described previously, the horizontal depiction of Lord Kelvin's wave-motion model is a viable, and perhaps optimal, method to depict radiant motion; it enables us to use the vertical axis to represent the "anatomy" (in fact the physical science) of all sounds: the partials of the overtone series. Before considering this, however, a look the nature of the overtone series itself is in order.

For those already uncomfortable with the seemingly arcane nature of mathematical notation, the overtone series can be presented and described in ways that may seem agonizing. But as we have seen, the basis is fairly simple: When an instrument (including a human voice) sounds C-262, that pitch, called the fundamental or first partial, is the frequency (262 Hz) of primary (if not *sole*), importance. A variety of instruments can sound C262, yet their voices can be distinguished from each other by their timbre. Beethoven demonstrates this in the restatement (or recapitulation) of the First Movement of his *Fifth Symphony in C minor*, Opus 67, by substituting a bassoon for a solo part in Movement 1's recapitulation, or restatement, while his listeners expect to hear a French horn.[50]

This is simply because the French horn had already been heard *twice*—at the transition in which the first theme group of the statement is succeeded by the second theme group; the French horn announces the abrupt transition from theme-group 1 to theme-group 2.[51] If listeners pay close attention to Movement 1, as performed by I Musici de Montreal,[52, 53] they will note that the French horn solo is first heard between 0:46 and 0:48 (minutes and seconds in real time) of the performance, signaling the change from the first theme group to the second.

Since Beethoven's Fifth Symphony's statement is often performed twice in succession, this means that the horn once more announces the transition, between 2:06 and 2:08 of the statement/exposition. In the restatement/recapitulation, the transition from the first to the second theme group occurs from 4:56 to 5:00, and the audience, now quite expecting the familiar the French horn's declaring the change, their ears are treated to the unexpected voice of a bassoon, sounding the same notes but in a surprising timbre. In a different application, a soprano, an alto, a tenor and baritone might sing the same note, but with some experience a listener should be able to recognize the singers as four different people. The overtone series makes such distinction possible. It also facilitates allusions to visual aspects in musical terminology (as mentioned, "tone color" and "chromatic scale") and also to tactile perception—musical *textures*.

Another remarkable feature of the overtone series is how it coincides with certain elements of the diatonic scales. In fact, the first five overtones (or the first six partials) of the series form what is known among musicians as "the Chord of Nature."[54] This refers to the natural consonance, or pleasing blend of pitches, of that chord. This may seem to suggest a purely subjective concept, and perhaps for that reason, musicologists at Southern Methodist University have provided the means for each of us to experience consonance and its antonym, dissonance, for ourselves.[55] This site identifies the various intervals that present themselves as consonant or dissonant. All the intervals in the chord of nature are consonant.

Although considerable deference is paid here to our Ionian ideal of consonance, this is not meant to imply that what to the Ionians would be dissonance should be excluded. To be sure, the "clash" of pitches could be even more dramatically observed if accompanied by a corresponding clash in colors, something very familiar to visual artists. Although this remains to be seen—both literally and figuratively—one of the best examples of such frankly distressing (to consonance-lovers) collisions is found in Beethoven's *Eroica*.[56] From 5:40 to 5:47, in the development of the *Eroica*'s first movement, Beethoven inserts a dominant minor 9th chord so dissonant that it must truly be heard to be understood. Judging from its sound, it seems as if its visual analog would torment many Western listeners, but be hailed as triumphantly spectacular by their Eastern counterparts.[57]

The first five overtones are identified as follows:

a) Tonic

b) 1st Octave Tonic

c) 1st Octave Dominant

d) 2nd Octave Tonic

e) 2nd Octave Mediant

f) 2nd Octave Dominant

Now, the Chord of Nature for C-130.81 (and rounded to the nearest 100ths) is: C-130.81, C-261.63, G-392, C-523.25, E-659.26, G-783.99.

While the overtone series is built upon elementary mathematical principles, the sheer numbers of overtones in a given musical composition offers challenges. Arguably the *least* complex of Ludwig van Beethoven's symphonies is his First, in C-Major, Opus 21.[58] Even so, if we were to examine only the first four measures of its introduction, we would need to consider more than 400 frequencies. As a matter of fact, the first notes sounded by the second oboe, A#-466.16, emits 12 partials of varying decibel values.

Below are the partials, their frequencies, the percentage of the total decibel volume each provides, their corresponding visible frequencies in THz, and the hue each most closely represents. These values are calculated using data from Dr. Carl Seashore's research:[59]

I/	**466.16**	*5%*	513	orange
II/	**932.32**	*76%*	513	orange
III/	**1398.48**	*3%*	384	violet
IV/	**1864.64**	*2%*	513	orange
V/	**2330.08**	*3%*	646	green/blue
VI/	**2796.96**	*3%*	384	violet
VII/	**3263.12**	*1%*	457	red
VIII/	**3729.28**	*7%*	513	orange

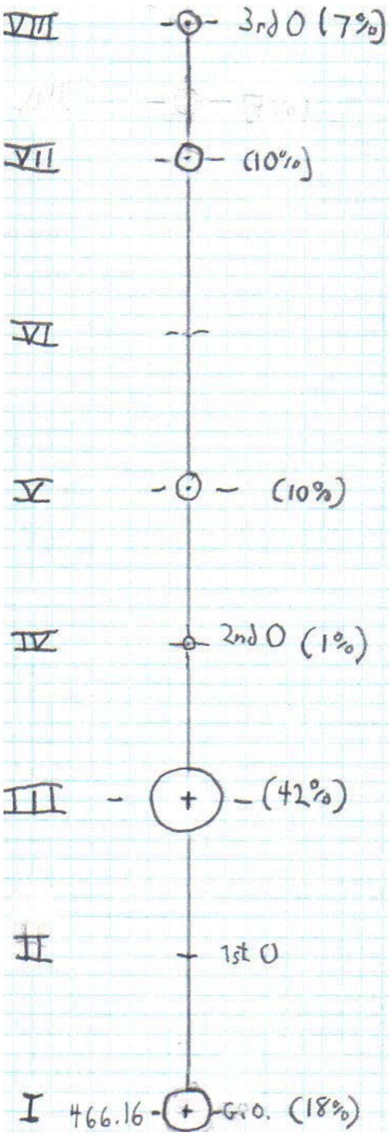

Figure 4

In the basic sketch of the translation into visual form, the overtones' visual(s) (or **ov(s)**) appear in this manner [Figures 4, 5]:

The scale might necessarily be reduced, bringing the ovs closer together. The size of the ovs is inversely proportional to their frequencies in Hz; the more cycles there are per count (cpc) the smaller the ovs must become. Meanwhile, the intensity of each ov is proportional to each overtone's decibel-volume. Figure 6 is an oversimplified sketch using an inaudible frequency (2 Hz) in red rather than green (2 Hz corresponds most directly with octaves of "C").

Nonetheless, it helps to illustrate appearance of an overtone that is sounded for one (1) second. The ovs simultaneously travel left and right of the invisible y-axis until they fade away before reaching the left and right sides of the screen or monitor. In cases where the note sounded slurs upwards, from G-192 to D#-304, for example, the ov to the right of the y-axis would also curve upwards [see Figures 5, 6, 7].

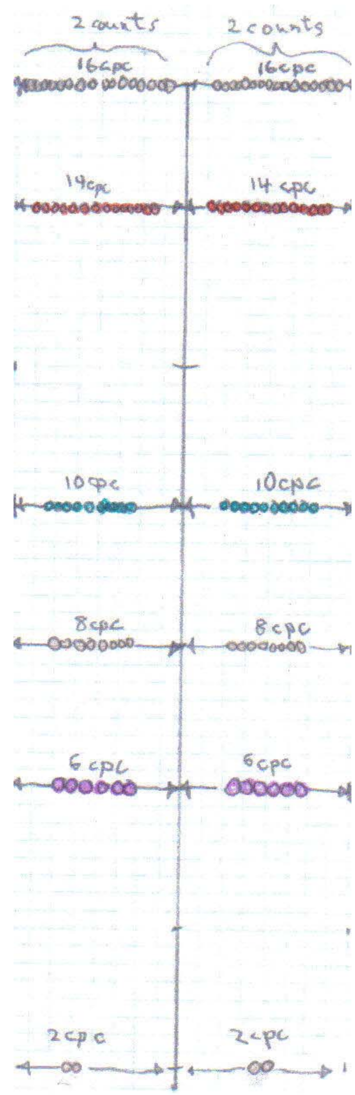

Figure 5

The visual representation of music as discussed in this paper was inspired by the Luxatone developed by H. Spencer Lewis and by Michelson's description of Lord Kelvin's torsion-driven wave model. However, the methods for integrating the overtone series into the proposed art form, making optimal use of modern computer technology, are many. Interested persons are invited to suggest possible approaches. One researcher suggests that CAS would be of particular interest to those whose vocations and / or avocations include art, music, and computer technology, although all input is certainly welcome. The truly optimal application might prove to be something different than envisioned here.

The First Second's image would appear as:

The Second Second's image would appear as:

The Third Second's image would appear as:

and so on...

Figure 6

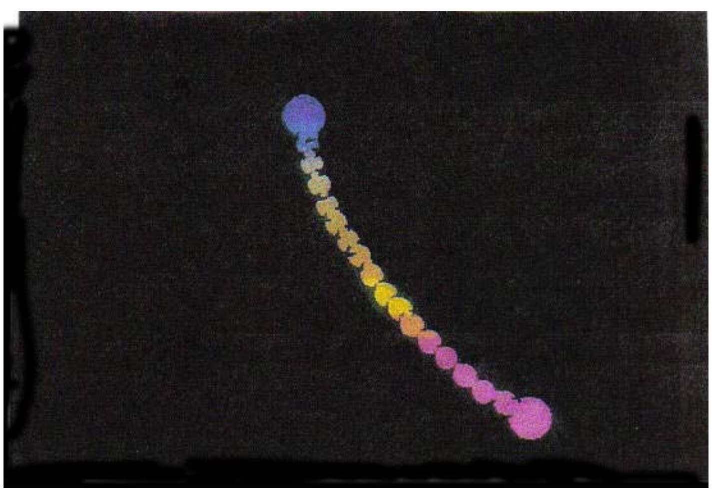

Figure 7

Conclusion

Chromacoustics provides insights into the operation of well-concealed natural laws. In addition, it can furnish beneficial results through instructional and therapeutic applications. Among these are means to provide enhanced tools for teaching the hearing-impaired. It has been suggested that CAS might very well shed additional light on the topic and possibly even contribute to improved learning (including higher IQ scores), a better understanding of synesthesia, and a means to guide perception. We might well have a basis to explore the ways in which other sensory stimuli, those involving touch, smell, and even taste, relate to seeing, to hearing, and to each other. The manner by which we perceive the manifestations of vibratory rates is intersensory: we sense the lowest rates tactilely, the somewhat higher rates acoustically, and the much higher rates visually. Taste and smell deal with frequency-based stimuli as well, but lie outside the scope of CAS.

As noted above, Replication (or lack thereof) has generally been a challenge in this type of research because of variations among test subjects and because of factors not yet well understood, and further systematic investigation is needed.

Although the merits in describing the visual presentation of CAS in the preceding (essentially linear) manner seem to be well worth pursuing, there might also be considerable—and perhaps even considerably *more*—benefit in applying the *kaleidoscopic* method to the visual display. To be sure, sound travels in a virtually infinite number of directions at once, and while this phenomenon is difficult to imagine—and even more difficult to present in a visual format—some existing art forms began addressing this challenge, in a limited manner, long ago. One need only consider the examples of the mandalas. The true challenge may be to adapt modern technology to demonstrate what Nature has been accomplishing for eons.

Acknowledgments

I wish to acknowledge a great debt to Dr. Burt Fenner, Professor Emeritus of Music, The Pennsylvania State University, my personal mentor (gratis) during the early years of my research, and Mrs. Sonya Oldland, reference librarian and music scholar of the Dauphin County (Pennsylvania) Library System. I am particularly indebted to Melanie Richards for her generous assistance and encouragement in the pursuit of this endeavor, as well as to David Stein, for his abundant assistance and support.

APPENDICES

Appendix A: Musical Terms

At this point, brief descriptions of key terms could be helpful. Striking a tuning fork produces what many of us would quickly identify as a "note," but if we choose not to refer to written musical notation, we might call it a "tone." With the aid of online musical dictionaries we can define other relevant terms. To these characteristics, one might add rise times and decay times (which themselves can vary among harmonics):[60]

1) **Pitch:** The highness or lowness of a tone, as determined by the number of vibrations in the sound.
2) **Scale:** A succession of tones. The scale generally used in Western music is the diatonic scale, also known as the Ionian mode or the Major scale, consisting of whole and half steps in a specific order.* A scale begins on a given note or pitch, and ends with a note or pitch having a frequency twice that of the beginning note.
3) **Chromatic scale:** A scale composed of twelve half steps.
4) **Octave:** The eighth tone above a given pitch, with twice as many vibrations per second, or below a given pitch, with half as many vibrations.
5) **Frequency:** The number of times a wave *cycles* (or *repeats*) in a given amount of *time*. Frequency is measured in units called *Hertz* (Hz), which equals *one cycle per second*.

6) **Overtones:** The almost inaudible higher tones, which occur with the fundamental tone. They are the result of the vibration of small sections of a string (instrument) or a column of air. Other general terms for overtones are *partials* and *harmonics*.
7) **Resonance:** Reinforcement and intensification of sound by vibrations.
8) **Texture:** The term used to describe the way in which melodic lines are combined, either with or without accompaniment.

*That order is: a whole step (from C to D), followed by another whole step (D to E), then by a half step (E-F), then by three whole steps (F to G, G to A, then A to B), and completed by an half step (B to C); to state this more succinctly, the steps are: w, w, h, w, w, w, h. Most of us are also familiar with the Aeolian mode, also known as the minor scale, in which the step are arranged as follows:
w, w, h, w, w, h, w, w. Then, as noted above, the Chromatic scale contains only half-steps—12, to be precise.
These are two of the seven Greek modes; the others include the Dorian (w, h, w, w, w, h, w), the Phrygian (h, w, w, w, h, w, w), the Lydian (w, w, w, h, w, w, h), the Mixolydian (w, w, h, w, w, h, w), and the Locrian (h, w, w, h, w, w, w). All of these are arranged in permutations of five whole and two half steps. But there are many others, from Turkey, Arabia, Thailand, India, Japan, and China. There can be as many as fourteen notes in a given mode, and the total number of recognized modes worldwide is 1,192.[61]

Appendix B: An Alternate Presentation of Partials' Decay

If instrumental timbres were to be represented by single frequency, the weighted mean would be a viable option. Although Dr. Carl E. Seashore's research is presented in greater depth (and with proper attribution) below, here is an abbreviated examination of his data regarding the timbre of the French horn (and specifically the first French horn's part) in the introduction to Ludwig van Beethoven's *Symphony No. 1 in C Major*, Opus 21). Its first note's frequency analysis is as follows:

26% of the horn's total volume or "loudness" is sounded through the fundamental or first partial, which is F# - 739.99 Hz;
71% through its first overtone or second partial, F# - 1479.98,
2% through its second overtone or third partial, C# - 2219.97, and
1% through its third overtone or fourth partial, F# - 2959.96.

If, for any reason, all four partials cannot be represented separately, they may be represented through their weighted mean: 739.99 x 0.26 = 192.40; 1479.98 x 0.71 = 1050.79; 2219.97 x 0.02 = 44.40; and 2959.96 x 0.01 = 29.60. The mean of these products is determined as follows: 192.40 + 1050.79 + 44.40 + 29.60 = 1317.19; 1317.19/4 = **329.30**. This is, in fact, a frequency of E.

Now if the second and third overtones, the third and fourth partials, are omitted, the fundamental and first overtone, the second and third partials, would then comprise, respectively, 27% and 73% (26%/97% = 27% and 71% /97% = 73%). 739.99 x 0.27 = 199.80 and 1479.98 x 0.73 = 1080.39; 1080.39 = **540.19**. This frequency is 54% of the interval from C-523.25 to C# - 554.37.

In this representation, the note not only deceases in Hz value but also becomes, in effective, a ¼ tone, which is of course accommodated by the 24 note scale.

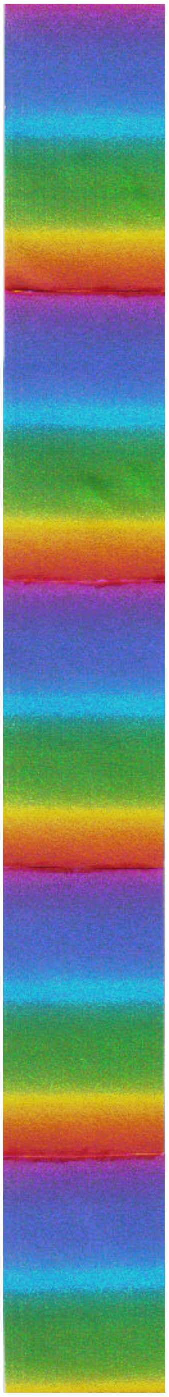

Figure 8

Appendix C: Mathematics of the Overtone Series

The arithmetic of the overtone series is presented here in order to explain how it contributes to the art form being proposed, and a separate examination of that arithmetic is provided in order to describe the beauty of its very simplicity. The relationship of the overtone series to the elements of musical harmony is itself one of remarkable beauty to the mathematician, as well as to the musician, although the details of that relationship are rather complex. The simple arithmetic of the diatonic scale provides the best example; by using the words "Tonic" and so forth, I am actually referring to the frequencies of the same:[62]

a) Tonic = Tonic times 1 (or 1.0000)

b) Supertonic = Tonic times 1+1/8 (or 1.1250)

c) Mediant = Tonic times1+1/4 (or 1.2500)

d) Subdominant (64/48, 1+1/3 (or $1.\underline{3333}$; here the underscoring indicates that the series of digits continue indefinitely)

e) Dominant = Tonic times 1+1/2 (or 1.5000)

f) Submediant = Tonic times1+2/3 (or $1.\underline{6666}$)

g) Leading Tone = Tonic times1+7/8 (or 1.8750)

h) 1st Octave Tonic = Tonic times 1+1/1 (or 2.000)

The spectrum-underlay [Figure 8] is intended to accommodate quarter-tone modes and is necessary. Restricting the study of Chromoacoustics to the Ionian and Aeolian modes (excluding at least 1190 others already identified) would be an exercise in shortsightedness. The rudimentary "artwork" manages to achieve what little one can see by using the Spectrum-underlay and placing holes in a black overlay sheet at the appropriate locations. Michelson's plates are far better examples.

Some mathematical shorthand might help explain the overtone series' relationship to the diatonic scale.

Note that the 1st Octave Tonic can be written in cardinal fashion as "Octave 1's Tonic." Although this may seem insignificant, "1" can also be denoted as 2 raised to the zero power, or 2^0. The Tonic is zero octaves above itself—to state what might be obvious. It becomes, however, quite significant, when we note that Octave 1's Tonic is also 2^1 (a.k.a. 2) times the Tonic. Moreover, Octave 2's Tonic is 2^2 (or 4) times the Tonic. Octave 3's Tonic is, of course, 2^3 times the Tonic, and so forth.

But the octave's number has more uses. The 1st overtone or 2nd partial is twice the frequency of the fundamental, or 1st partial, both of which are in fact the Tonic itself. Only one fraction needs to be multiplied by the Tonic to reach the 1st overtone, 2nd partial…or Octave 1 Tonic. That fraction is of course 1+1/1, which is (obviously) 2. Both the quantity of mixed-number fractions (which identify the overtones), and the common denominator of those fractions, is 1. The numerator is also 1. This may seem insignificant, but that is deceptive.

The 2nd overtone or 3rd partial is 3 times the Tonic; this much we already know; we can also easily determine that it lies somewhere between the Tonics of Octave 1 and Octave 2. Octave 1's Tonic is 2^1 x the Tonic (which becomes the 1st overtone/2nd partial), and Octave 2's Tonic is 2^2 x the Tonic (3rd overtone/4th partial). There are also 2^1 steps between the 1st and 3rd overtones, each representing an overtone and each represented by 2^1 mixed-number fractions…1+1/2, and 1+2/2 or 2; multiplying each of these by the Octave 1's Tonic provides the frequencies of the overtones in question. If 1 is essential to identifying the 1st octave, it is at least as essential as a power of 2 in understanding its relation to the overtone series.

The importance of 2 to the 2nd Octave can now be anticipated. Two represents a) the number of the octave above the Tonic, b) the power to which 2 is raised in order to determine how many mixed-number ("1+") fractions (and the corresponding number of overtones) are to be encountered on the way to the next octave, as well as the common denominator of those fractions, and finally, the number by which those fractions are to be multiplied in order to calculate the overtones' frequencies. As for the numerators, they begin with 1 and continue in integer intervals (1, 2, 3, etc.) until the numerator equals the denominator. In other words:

For Octave 2, the sequence is 2^2 x the Tonic, 2^2 x 1 + $(½)^2$, 2^2 x the Tonic x $1+({}^{2}/{}_{2})^2$, 2^2 x the Tonic x $1+({}^{3}/{}_{2})^2$, and 2^2 x the Tonic x $1+({}^{4}/{}_{2})^2$; if we use "T" as shorthand for "the Tonic," we can rewrite the preceding as <u>4T x 1¼,</u> <u>4T x $1^2/_4$</u>, <u>4T x 1¾</u> and <u>4T x 2</u>. Now that we have established the process, we can streamline the data for Octave 3, bearing in mind that $8 = 2^3$:

$8T \times 1^1/_8$, $8T \times 1^2/_8$, $8T \times 1^3/_8$, $8T \times 1^4/_8$, $8T \times 1^5/_8$, $8T \times 1^6/_8$, $8T \times {}^7/_8$, 8T x 2.

Now we can see how overtones can be found. This can also be done mathematically:

In each octave above "octave 0" (i.e., n = 0), which contains T, we have a set of overtones that increases exponentially as we progress through the octaves. If **n** is the number of octaves above T, we have for each octave a list of frequencies, the overtones, constructed as follows:

Tx for all x such that:
2^(n-1) < x <= 2^n (and x is an integer)
<u>or</u>

Tx for all x such that:

$2^{(n-1)} < x \leq 2^n$ (and x is an integer)

Appendix D: An Alternate Description of the Relationship between Audible and Visible Frequencies, and the Frailties of Human Prediction

The physical differences between sound and colored light have led many to conclude that any attempt to link the two would necessarily be limited to highly subjective impressions. Even among those who sense the suggestions of color in certain timbres and chords will likely disagree upon which colors these auditory events suggest. It may seem that such suggested relationships between sound and color would necessarily be arbitrary, or at best superficial. Expressed in a more general fashion, with implications reaching well beyond the topic of music, it appeared reasonable to conclude that if this sort of relationship exists, it would have been discovered by now.

This sort of conclusion regarding inferred connections is probably as old as civilization itself. And at least one of its rebuttals has become an urban legend. There is no reliable evidence that Charles H. Duell, Commissioner of the U. S. Patent Office in 1899, actually said, "Everything that can be invented has been invented,"[63] but the story enjoys recurring popularity. Perhaps it serves as a cautionary tale that even supposed authorities are not infallible, and that everyone assumes to be prescient at their own risk.

Regarding science, the facts are even more remarkable. Albert Michelson and William Thomson, Lord Kelvin—one of the grand pioneers of nineteenth-century physics, and for whom the Kelvin temperature scale is named[64]—are well known in this field of study. It is ironic that these illustrious persons, who helped to inspire the concept of CAS**,** somehow underestimated the world of science and of scientists. Many of Dr. Michelson's visions would prove to be prophetic, and yet a statement often attributed to him seems to lack foresight: "…the grand underlying principles have been firmly established...further truths of physics are to be looked for in the sixth place of decimals...."[65] A similar mindset, but with greater *hauteur*, was displayed by Lord Kelvin. In 1895 he stated to the Australian Institute of Physics that "…heavier-than-air flying machines are impossible…" The very next year he added, "I have not the smallest molecule of faith in aerial navigation other than ballooning...I would not care to be a member of the Aeronautical Society."[66]

Seven years later, on December 17, 1903, Wilbur and Orville Wright launched the first successful powered and piloted flight, in a heavy-than air flying machine, in history. [67]

And his lordship did not stop there. His circumscribed views included the entire scope of physics. Whether or not Michelson made the statement mentioned in the preceding paragraph, there are no doubts concerning Kelvin's perspective. In 1900, before the British Association for the Advancement of Science, he confidently declared, "There is nothing new to be discovered in physics now. All that remains is more and more precise measurement."[68]

In 1905, of course, Albert Einstein added a whole new dimension, and in fact an entirely new paradigm, to physics. He reported that time (and later, space) itself was not absolute,[69] and that matter could be transformed into energy in terms of the speed of light (186,282.4 miles per hour, or 299,792,458 meters per second)[70] by the equation: $E = mc^2$.[71]

Setting aside the notion that an idea is false simply because it has yet to be proven true, one can begin to examine the realms of optics and acoustics (the study of sound) for clues of a possible connection between these two disciplines. It is quickly recognized that both involve forms of radiation, and that both forms are measured in cycles per second or Hertz (Hz). But an enormous difference in Hertz values separates these two forms; if Middle C, 261.626 Hz, is used as an example,[72] it is only one-quadrillionth the frequency of deep red, the "slowest" frequency of visible light at 384×10^{14} Hz.[73]

Also, sound requires a medium, such as air or water, through which to travel, while light does not. Because of the difference in frequencies and propagation, there would seem to be no evident relationship between sound and color radiations.

Yet if one "gets back to basics," so to speak, one of the most basic tools of science, the counting system, needs to be examined more closely. The decimal counting system, based upon the quantity of ten, probably originated because barring mishaps everyone carries ten counting tools everywhere they go—five on each hand. The decimal or base-10 system has 10 elements, including zero and excluding the value of ten itself: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.[74]

This system serves so well that other base systems are rarely considered, especially outside the scientific community. But other systems can be employed, and in fact, three other such systems are very useful when computers are doing the counting. These are the binary or base-2, the octal or base -8, and the hexadecimal or base-16 systems. Any whole-number value greater than one can form the basis of a counting system; moreover, every such system would consist of the same number of elements as the base-number, including zero and excluding itself. The binary system has two elements, the octal has eight, and the hexadecimal has 16. All such counting systems have something else in common: when the largest (in quantity) of the elements has been reached, the next quantity begins a new series and ends in zero. In base-10, for example, when a quantity ends in 9, the next highest whole number begins a new series; 09 is followed by 10, 19 by 20, 29 by 30…99 by 100, 999 by 1000, and so forth.

The elements of the three counting systems just identified are as follows: Note that because the hexadecimal or base-16 system requires more elements than the decimal or base-10, letters are included; 10 through 15 in decimal are represented by A through F, respectively: Binary: 0 and1; Octal: 0,1,2,3,4,5,6 and 7; Hexadecimal: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F.

Applying the series principle to the binary system, after 1, the next expression is 10 (which in decimal or base-10 counting is actually 2); after 11, the next is 100 (in decimal, 4); after 111 (decimal: 7) , the next is 1000 (decimal: 8). Likewise, in the octal system, after 7, the next expression is 10 (decimal: 8); after 17 (decimal: 15) the next is 20 (decimal: 16) , after 77 (in decimal, 63), the next is 100 (decimal: 64), and after 777 (decimal: 511), the next is 1000 (decimal: 512). And the hexadecimal system approaches the surreal: after F (in decimal, 15), the next expression is 10 (decimal: 16), after 1F (decimal: 31) the next is 20 (decimal: 32), after FF (decimal: 255) the next is 100 (256), and finally, after FFF (decimal: 4095), the next is 1000 (decimal: 4096).[75]

The octal and hexadecimal systems are included here, 1) to provide additional examples of non-decimal counting systems, and 2) to note that these are "space-saving" alternatives to the binary system. It might seem that because it works so well for humanity, the decimal system is a "natural" counting system, and in fact it is elemental to a crucial subject, the overtone series,[76] which shall soon become evident. But the overtone series itself depends upon the most basic system—the binary.

The binary is obviously the most basic because no simpler system can be constructed. But it has a further distinction: it is manifested in the natural phenomena observed in the study of acoustics. In other words, it is the natural counting system of sound. Tradition identifies Pythagoras, another luminary who appears in later paragraphs, as the discoverer of the musical octave. Specifically, he discovered that if a vibrating string were reduced in length by half, its frequency would be doubled; the resulting sound would be the same as the base or tonic pitch, sounded when the string was at its former length, but an octave higher.[77] The octave provides substantive evidence of music's relationship to the binary counting system: each time one ascends the musical scale to a new octave, a new series is begun.

The great significance here is that one can, as least mathematically, continue to ascend the octaves until the frequencies can no longer be heard even by those with the most acute sense of hearing, as for example, canines, but the frequencies continue to exist. Eventually the frequencies can be seen, and despite their material differences from those of frequencies that can be heard, there is a clear mathematical (specifically, a simple arithmetic) relationship between the two. At present there appears to be no other manner in which sound and color are directly related, and from as artistic perspective, no other relationship is required.

Visible colors are often expressed in wavelengths, although for CAS, frequencies are the key to sound-color correspondences. Conventionally, visible colors are manifested in ranges:[78]

Color:	**Wavelength Range in Nanometers:**	**Frequency Range in Terahertz:**
Red	708-622	384 - 482
Orange	622-597	482 - 503
Yellow	597-577	503 - 520
Green	577-492	520 - 610
Blue	492-455	610 - 659
Violet	455-390	659 – 769

Note that visible colors are much more inclusive than audible pitches, so far as frequencies are concerned. For example, the color red occupies a range, a band from 384 to 492 terahertz. One THz equals 10^{12} or 1,000,000,000,000 (one quadrillion) Hz; there would then be 98 quadrillion possible distinct frequencies for red. If red's frequencies were to be expressed in scientific notation, the range would be 3.84 to 4.92 times 10^{14}. The typical or "average" hue for each color of the spectrum may be expressed as the midpoint of its given range (for red, this is 438 THz), and the border of each range form what is perceived as the mean hues: 492 THz is red-orange, 503 THz is orange-yellow, and 520 THz is yellow-green. The terms "deep red" and "deep violet" are used to identify the lower and upper limits of the visible light spectrum:

Color:	**Mean Wavelength in Nanometers:**	**Mean Frequency in Terahertz:**
Deep Red	780	384
Red	462	433
Red-Orange	622	482
Orange	609.5	492.5
Orange-Yellow	597	503
Yellow	587	511.5
Yellow-Green	577	520
Green	534.5	565
Green-Blue	492	610
Blue	473.5	634.5
Blue-Violet	455	659
Violet	422.5	714
Deep Violet	390 (780)	769 (384)

As is evident in the first chart, the classical presentation of the visible-light spectrum begins with red and ends with violet, but there is another way to consider colors. The CIE, the *Commission Internationale De L'Eclairage,* or the International Commission on Illumination, recognizes a range of non-spectral hues between red and violet, known as *magenta*, which has long been familiar to artists.[79]

If the binary counting system were employed as readily as is the decimal system, this connection between frequencies of the spectral colors for red and violet would be more apparent; as it is, their roles as a link between violet and red is intuitive. Moreover, the wavelength of deep violet is precisely *half* that of deep red, while the frequency of deep violet is nearly *twice* that of deep red (the former is 769, the latter is 384; 384x2 = 768). Magenta can be produced via light by combining the mean primary frequencies of red and blue.[80]

Because magenta is a color that is not a single wavelength, it is non-spectral and, some contend, should not be considered to be a color at all. If so, then neither should brown be considered to be a color. But colors exist to us as perceptions, whether they exist as a single wavelength or in combinations.[81] If the visible-light spectrum were to play a significant part in the effort to link sound and color naturally, it should demonstrate some sort of periodicity…it should return as a repeating series of some kind. Surprisingly, it *does*, at least under certain circumstances.

The spectrum is a discontinuous band when white light which is refracted through a prism; this is fairly common knowledge.[82] But this is essentially a linear event; if the prism is quadratic (such as the grooved, reflective surface of a CD), the spectrum is repetitive. And as Dr. Michelson demonstrates, the continuous nature of the spectrum is observable in the reflective surface of soap film. In other words, the series principle applies here, if only for a few repetitions. And the compact diskette reveals something else, something quite significant, about light wavelength of either 390 or 780 nanometers, and a frequency of either 769 or 384: they are both *effectively invisible*. Anyone with a clean-surfaced CD and a light source can verify this. And while the physics of this phenomenon may be fascinating, it is incidental to the art, and even to the psychology, that CAS seeks to address. Its implications for physics would certainly be worthy of investigation, however that is not presently the objective of the art-form.

Every audible frequency, doubled and then redoubled often enough to reach the vibratory rate of visible light, would be found in one, and only one, of the spectrum's discreet ranges. For example, one of the frequencies for Middle C is 256 Hz. In binary, 256 is 10000000, or **1000 0000** (seven zero-places). Its arithmetic correspondent in the visible-light spectrum would be: 1 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 (forty-eight zero-places), or **562,949,953,421,312** in decimal.

C-256 is chosen because it is the simplest value of C to process mathematically for a correspondent in the visible spectrum, based upon what may be called the octave premise. Simply expressed, a given pitch has as its correspondents all those frequencies which are one or more octaves above or below it, whether audible or not, whether visible or not. And, as noted above, were the binary counting system a practical alternative to the decimal system, the correspondence would be more easily recognized. For example, the quantity of 5 in decimal is expressed as 101 in binary form. In binary, its correspondents would be easy to find: they would include such values as 1010 (decimal: 10), 10 1000 (40), 10 1000 0000 (640), and 1010 0000 0000 0000 (40,960), and any other binary expression in which "111" is followed by a set exclusively of zeroes.

C-256 helps to explain a crucial facet of the octave premise, the translation factor 1. This simply means that every octave correspondent in the audible-pitch range has as its visible correspondent the same value as C-256: 562,949,953,421,312—i.e., 563 THz. This includes C-128, C-64 and C-32 (and, theoretically, C-16, although as the first pitch of Octave "C0," it lies outside the range of music, and might be just as easily be felt as heard). It also includes C-512, C-1024, C-2048, C-4096, and C-8192, which begins C9. "Undertones" do not sound in the "overtone" series—but of course they are related as octave pitches.

It may be deduced from the term translation factor 1 that there is a translation factor 2. This portion of the octave premise permits the transformation of 384 THz into 768 THz, and vice versa. More inclusively, it also permits visible correspondents which exceed the frequencies of the visible-light spectrum to be halved, or divided by 2, to place them within the spectrum range.

Less apparent but just as useful is the fact that the number of zeroes in the zeroes-only set indicates that the value of the binary express is simply the original value, 5 in this instance, multiplied by 2 raised to whatever power is indicated by the total number of zeroes in that set. For 1010 0000 0000 0000, the expression for 5 (101) is followed by 13 zeroes; $5(2^{13}) = 5(8,192) = 40,960$. As shown above, the number of zeroes in the exclusive set, separating 1000 000 (256) from its visible-spectrum correspondent, is 41. As a value of Middle C, C-256 begins what is known among musicians as Octave C4 (C1 begins the octave of the lowest frequencies in music).[83]

The octave premise is now applied to the standard frequencies for the chromatic scale beginning at A-220 or A3. The visible correspondents would, based upon translation factor 1, also apply to the chromatic scales of A1, A2, A4, A5, A6, A7, A8, and A9. The pitches (frequencies in Hz) are multiplied by 2^{41}, or 2,199, 023,255,552, as explained above:[84]

Frequencies in Hz	**Frequencies in Thz (rounded to the nearest whole frequency)**
A3-220.00	484
A#3/Bb3-233.08	513
B3-246.94	543
C4-261.63	575
C#4/Db4-277.18	610
D4-293.66	646
D#/Eb-311.13	684
E4-329.63	725
F4-349.23	768
NOTE: Here translation factor 2 is applied:	
F#4/Gb-369.99	407 (half of 384)
G4-392.00	431 (half of 862)
G#4/Ab4-415.30	457 (half of 913 = 456.5)
A4-440	484 (translation factor 1)

Appendix E:

The Story of Luxatone, the Master Color Organ

(NOTE: The Luxatone was devised and constructed by H. Spencer Lewis in the experimental laboratory of the National Headquarters of the Rosicrucian Order, AMORC, a non-religious, non-profit organization at San Jose, California.)

Color Organs

Ever since the philosopher Aristotle suggested the idea of a relationship between color harmony and sound harmony in his work entitled *De Sensu et Sensibilibus*, musicians and artists in many lands and in various periods of the development of art and music have attempted to create an instrument that would demonstrate the psychological synthesis of nature's colors and nature's sounds.

Early in the sixteenth century Arcimboldo, a Milanese painter, invented a system of color harmony based upon a color scale closely related to the musical scale, and no doubt Sir Isaac Newton was impressed by Kepler's "The Harmonies of the Universe," for he and many other scientists as well as philosophers believed that there was some mysterious fundamental relationship between colors and sounds, and that there might be a justification for the thought that the "Music of the Spheres" was possible of demonstration. Newton was greatly impressed by the fact that there was very evidently a relationship between the relative spaces occupied by the principal colors of the spectrum, and the rate ratios of the notes of the diatonic scale. All attempts at an arbitrary division of the spectrum into seven principal colors composing an octave led to no satisfying results until science determined in its experimental laboratories that there was a definite relationship between the rates of vibration of a note of music, and the rates of vibration of color.

Even in the earliest days psychologists were impressed with the possibility that the effects of music upon the human consciousness were not purely auditory, but that some harmonic key of musical vibration equivalent to a rate that would produce a color affected some faculty or functioning of the human consciousness and affected a mental impression that accompanied the stimulation produced by the sound of the note.

Musicians, and especially those who devoted much time to the composition of music, were often led to see that in creating a theme for any passage or movement of a composition, they were assisted in the arrangement of the notes by selecting those which seemed to merge into the subtle consciousness of the theme. They attempted to select elements of sound that agreed with the elements of color composing the theme-picture held in their consciousness during the time of composing. It was for this reason that many eminent masters of music spoke of tone pictures, symphonies of color and sound, and similar expressions which were intended to convey the idea that a perfect musical composition devoted to any definite theme aroused in the human consciousness a reflection of the pictorial theme held in the mind of the composer.

Such ideas, of course, were very vague, and rather mystical, but, nevertheless, intriguing not only to musicians and artists, but to physicists. It was not until the Jesuit, Louis Bertrand Castel, an eminent mathematician, devoted much of his time to the subject, that a workable foundation for the demonstration of the various theories was prepared. His experiments were published in a book called *La Musique en Couleurs* in 1720 and in another book published in 1763, six years after his death. In these books he described a contrivance he had experimented with, and which he called a Color-Clavessin. While Aristotle is probably the true father of the idea of color music, Castel is undoubtedly the pioneer in scientific methods to demonstrate the laws involved.

Not more than ten or twelve color organs have ever been constructed and demonstrated in a practical manner up to the present period of time *(Editor's Note: late 1930s).* The tremendous cost involved, the many months and years of laborious experimentation, and the many branches of artistic and scientific knowledge required, have prevented any commercial concept of color-music, and has made the construction of color organs beyond the capabilities of those who have recognized its fundamental possibilities.

Of the earliest experimenters, we find that a D. D. Jameson published a pamphlet in 1844 dealing with the relationship of music and colors, and later on devised a small organ to merely demonstrate its possibilities. In 1893 William Schooling published a small article dealing with the subject, and suggested the use of vacuum tubes in connection with the keyboard. In the same year Professor Alexander Wallace Rimington, Professor of Fine Arts in Queen's College, London, conceived the idea of a color organ constructed along entirely new lines, and in 1895 demonstrated the organ in St. James Hall, London. In 1911 he published a book, *The Art of Mobile Color*, but admitted in his text that he had not found or used any of the laws or principles which determined the precise relationship of individual colors to the individual notes of the musical scale.

Mary Hallock Greenewalt, an American pianist, was one of the experimenters in the field of color music in recent years, and in 1919 Thomas Wilfred of Denmark completed an instrument for projecting colors upon the screen independent of sound, and demonstrated this device in America, and in 1925 in Paris, London, and Copenhagen. But this had naught to do with color-music.

In Australia Alexander Burnett Hector devised a color organ using incandescent lamps combined with vacuum tubes. Mr. M. Luckiesh, an American illumination engineer also experimented with similar devices. Other experimenters have been M. Carol Berard, and M. Valere Berneird, both of France. In England, Leonard C. Taylor, Claud Bragdon, and Adrian Bernard Klein constructed experimental instruments for the purpose of testing the theories involved.

Strange Laws Involved

Nearly all of these pioneers' experiments have failed because of the lack of knowledge regarding the precise relationship between definite colors and definite notes of both the musical and spectrum scale. It has always been admitted by those who wrote theoretically on the subject that if the true relationship between color and sound was established, playing of a harmonious chord on the organ would result in a harmonious blending of related colors on a screen, and the playing of a discord or inharmonious chord would result in the projection upon the screen of colors that would clash because of their inharmonious relationship.

The two interesting features of the theory were never realized in the fourteen known models of color organs that have been made since Aristotle suggested the idea, except in the case of a miniature color organ made by H. Spencer Lewis in 1916 in New York City, and exhibited there for two months before a group of Rosicrucian scientists, musicians, artists, and prominent persons as a preliminary to the complete study of the harmonics of music and color for the purpose of evolving a definite system of color and sound symphony.

Mr. A. Wallace Rimington, while Professor of Fine Arts at Queen's College, London, said: "Whatever may be the divergence of opinion as to how far the analogies between color and sound extend, one thing at least is certain; namely, that the color-music opens up a new world of beauty and interest as yet, to a great extent, unexplored."

Sir Hubert Von Herkomer, R. A., an eminent authority, writing on the subject said: "It has been denied by some that color suggests musical sounds, and that musical sounds suggest color, but it is safe to say that a psychological affinity is felt by artists and musicians between sound and color; hence the use of common terms of expression between them. The painter speaks of a note in a painting, and the musician speaks of a tone picture. Let me say here that the color-sense is by far the most sensitive and delicate of all the faculties that go to the making of the artist's brain."

The great Physicist, Professor Albert A. Michelson, wrote in 1903 as follows: "Indeed, so strongly do these color phenomena appeal to me that I venture to predict that in the not very distant future there may be a color art analogous to the art of sound—a color-music in which the performer seated before a literally chromatic scale can play the colors of the spectrum in any succession or combination, flashing on a screen all possible graduations of color, simultaneously or in any other desired succession, producing at will the most delicate and subtle modulations of light and color, or the most gorgeous and startling contrasts and color chords! It seems to me that we have here at least as great a possibility of rendering all the sensations, moods, and emotions of the human mind as in the older art."

Pictorial Music

In the foregoing statement by Professor Michelson is summed up briefly the real quest and goal of all who have experimented with the color organ, and in the Luxatone now perfected after many years of research, study, experimentation, and careful construction on the part of H. Spencer Lewis, we have a living, vibrating, masterful demonstration of this new instrument of art. The musician seated at the Luxatone becomes an artist in color as well as in sound, but the artist need center his or her thoughts only upon the laws of musical composition and harmony. As the artist plays in any mood and to express any theme that the artist's inner consciousness may visualize, he or she will find the tones of music interpreting the theme and mood, while on the large satin screen before the artist will be portrayed with all of the masterly strokes of a genius in art the pictorial representation of the theme being expressed by the music. Harmony, rhythm, and movement with all of the incidentals of progression and counterpoint are made visibly manifest on the screen as with the technique of a painter.

If the organist plays a militaristic theme, the pictures painted upon the screen by the notes of music are those which the human consciousness recognizes as typically associated with warfare, strife, and contest. The pictures are as invigorating, inspiring, and arousing as is the music. A simple folksong or one which expresses the atmosphere of a pastoral scene played upon the organ will produce pictures that suggest quiet and peaceful landscapes. Musical themes interpreting rippling waters, gentle breezes, or storms will produce pictures of a like theme upon the screen.

The pictures are painted in fixed, and mobile colors, and with symbolical designs and elements of form and color in rhythmic motion. The color painting is done automatically by the notes of the music, and if any selection is played a second time in an identical manner, the pictures produced by the music will be identical. The pictures upon the screen often change at a rate of from five to seven a minute, while many of them remain fixed for several minutes gradually evolving or dissolving into others.

Not a Commercial Proposition

The Luxatone is not a commercial proposition since it is not for sale, and duplicates of it cannot be made commercially profitable. The purpose in creating it and in devoting such a large amount of time and money to its perfection has been solely to demonstrate the psychological facts pertaining to the relationship of color and music as taught by the Rosicrucians in the middle ages, and at the present time in connection with their doctrines of transmutation, in which they have always claimed that the rates of vibration of all atomically constructed matter are related by harmonic cycles and periods, and that by changing the rates of vibration of one element or one manifestation, the element or manifestation may be changed in nature. The recent demonstrations on the part of science in the fields of metallurgy have proved that gross elements can be transmuted into gold in accordance with the theory taught by the Rosicrucians.

But this process is of no commercial value because of the extreme cost involved in producing even a small grain of gold. The Luxatone is now the most recent and elaborate device for the demonstration of the transmutation of sound into color. It is said by those who have witnessed the preliminary demonstrations of the color organ that those who are deaf easily recognize the theme of a musical composition by the pictures produced upon the screen. Many eminent psychologists insist that the sound waves do create in a subjective form of our consciousness invisible pictures which we sense through a little-known faculty that may be brought into development, or awakened in some way, by a proper adaptation of sound pictures produced through color.

Appendix F:

The Relationship of Color to Sound: AMORC Achieves a Marvelous Scientific Victory in Its New Color Organ

by the Grand Secretary

Originally published in the *Rosicrucian Digest,* Vol. XI, No. 1 (February 1933), pages 7-11.

I know that thousands of our members will be interested in hearing about the two wonderful demonstrations of the new color organ created and built by the Imperator. This wonderful instrument is undoubtedly one of the most important contributions that the AMORC has made to science and the fine arts in many years; in many centuries; and do not forget that many of the most eminent musicians of the past were Rosicrucians and have been credited in the history of music with having made many other valuable contributions to the advancement of the art and science of music.

On Wednesday evening, January 4, the private premier demonstration of this new master color organ was given at the Francis Bacon Auditorium to a very select and important group of musicians, artists, scientists, instructors, and patrons of art and music who were present by special invitation to witness the performance of the largest and most perfected form of color organ ever built.

Four days later, on Sunday evening, January 8, a more or less public performance was given of the organ to which all of the membership of the Santa Clara Valley and a portion of the public were invited. Before speaking of the success and wonders of these two demonstrations, perhaps our readers would like to have a brief outline of the history of the color organ.

The Story of the Color Organ

[Editor's Note: in the original article, the text of the booklet, The Story of Luxatone, the Master Color Organ (Appendix E above) *was reproduced. The article then continues]:*

Marvelous Demonstration

On the evening of January 4, when this new and large master color organ was demonstrated for the first time, the Imperator gave a brief introductory explanation of the theory of the relation of color to sound and called upon the organist to illustrate the theory by the playing of the diatonic scale and other scales and the playing of simple harmonious chords and inharmonious dis-chords. Then, for a more perfect manifestation of the organ's possibilities, a wonderful program of music, song, and dance was introduced. During this program the organist, who had been previously instructed by the Imperator, played such numbers as Mendelssohn's "Spring Song," Chopin's "Funeral March," Lehar's "Merry Widow Waltz," Chopin's "Waltz," "Dardenella," "Dvorak's "Humoresque," Chopin's "March Polonaise," and Lemare's "Andantino." These numbers were selected because of the very distinct form and class of pictures and color combinations they would produce upon the screen and because of the difference in rhythm and theme.

As additional features and points of demonstration, the program was beautifully assisted by Madame Beatrice Bowman, a member of AMORC, and a former coloratura soprano of the Metropolitan Opera Company and the Boston Opera Company. She sang three especially selected numbers, the "Waltz" from *Romeo and Juliet* by Gounod, "The Last Rose of Summer" by Flotow, and "Comin' Thru' the Rye." Mr. Francis Beauchamp, a basso-chantant from San Francisco, demonstrated the beauty of the basso voice and the lower notes of the organ in singing two numbers: "Friend of Mine" by Sanderson, and "Drink to Me Only with Thine Eyes."

It was easily discerned that when the singers sang with the organ accompaniment, the microphone which picked up each voice and added it to the vibrations of the organ music, caused the voice vibrations to form undulations of colors which passed across the screen as though riding upon or being carried upon the waves of colored lights produced by the organ, and the marvelous principles of overtones and harmonics were demonstrated when Madame Bowman, with all of the rich, colorful, powerful tones which made her so popular in the opera a few years ago and so popular on the concert stage today, produced dual effects of colors by the overtones or harmonics of her voice; and the trueness of her notes was demonstrated when the pure tones of the voice agreed with the pure color values of the organ notes. Mr. Beauchamp also demonstrated the richness of overtones and the magnificent roundness of his chanting voice which reminded everyone of the tones heard in the chants of the greatest of the cathedrals of Europe.

As an additional feature of the demonstration of the rhythm and movement of the color in harmony with the rhythm and movement of the music, the Imperator introduced another member of the organization, Miss Ruth Prell, California's most popular aesthetic and operatic dancer, who selected for her performance the famous Flame Dance. The Imperator desired to demonstrate the poetry of motion as illustrated by the movement of the human figure in keeping with the rhythmic changing of the lights of the music and, therefore, the accompaniment selected for the dance was MacDowell's "Scotch Poem," a very beautiful organ number. Miss Prell performed the dance in front of the illuminated satin screen, thereby making her figure appear in black silhouette against the changing colors on the screen which at the same time affected the moving, flowing colors and streamers of her costume and trans-parent veil which she used so beautifully in illustrating the poetry of motion. The audience was enthralled.

Those who have visited the Francis Bacon Auditorium at Rosicrucian Park either at Convention time or at any other time will be able to visualize the magnificence of the screen on the occasion of the two demonstrations when we say that the organ screen occupied nearly the whole of the center of the great stage. The magnificent screen was made of the finest quality of white satin, hanging in folds that were carefully gauged at the rate of twelve folds to the linear foot so that each fold would give a frequency to the moving lights that was in keeping with the number of colors to the octave of the music. The screen was beautifully framed in gold satin and the entire stage was illuminated with a soft blue light that gave a very mysterious effect.

The organ used for this purpose was one that was built in Vienna, Austria, and is a special type of Harmonium imitating the various wind instruments of an orchestra and is especially appropriate for such a demonstration. Neither the organ nor organist were visible and the audience composed of well-known patrons of art and science and music of the Pacific Coast sat in a completely dark auditorium thereby being keenly appreciative of the least shade of coloring produced upon the satin screen. As each note of the organ was played a different color would illuminate the entire screen and reflect the light on to the countenance of those who sat in the audience, bathing them in the changing lights and having a very definite effect upon the psychic, emotional natures of each person present.

As the various chords of the lower notes were played the lights of a soft nature would make a background for the brilliant lights of the higher octaves which would shoot and dart across the screen in accordance with their position in the musical scale. The sharps and flats played merrily across the screen while the natural notes furnished shades and tones of unbelievable brilliancy and astonishing tone for there seemed to be more colors produced by this organ than the human eye has ever conceived of seeing in the solar spectrum or elsewhere. It must be borne in mind that the only true manner in which colors can be actually appreciated in their true form is through lights of a pure tone seen in this manner. The pigments of paints or inks cannot give the scintillating, translucent beauty of lights for all color is essentially of waves of light.

As some of the themes were played upon the organ or sung with the human voice there would appear combinations of fixed and moving colors grouped into designs and patterns that were suggestive of the East or of the West and often of peoples and their costumes and then again of scenes or architecture, landscapes, or sky and water.

Space does not permit me to speak of each number and the effects produced by it on the organ but I must speak of one as an example. Taking the last number on the organ, Lemare's "Andantino," which was composed by the organist of the great San Francisco Civic Auditorium and was later popularized into the song, "Moonlight and Roses." I wish to say that it was quite evident to everyone in the audience how and why a popular music writer could have found in Lemare's "Andantino" a theme for a song dealing with moonlight and roses.

When the "Andantino," was played upon the organ the beautiful sky with a few clouds and various forms of moonlight effects from the clouds and the landscape, spotted occasionally with bright colors of red and pink as though huge bouquets of roses were held in front of a moonlight landscape, made quite evident to everyone in the audience the theme which must have been in the mind of Lemare when he composed his beautiful number, which is generally looked upon as a California theme song. At times there were quite definite scenes of life, bodies of water like oceans with even huge ships like the *Majestic* or the *Leviathan* sailing in the moonlight. At other times there were mountains and forests, sunsets and pastoral scenes.

The "Funeral March" produced very weird effects, while "Dardenella" illustrated the syncopation that has evolved into our modern jazz form of music. A brief imitation of Chinese music produces all of the Eastern effects of looking into a mass of Chinese lanterns or a gift shop of Asian hangings.

At the Sunday evening performance, which was the second demonstration of the organ, Miss Emily Hardy, the well-known concert and radio entertainer, sang two numbers which produced beautiful effects and illustrated the beauty of the tones of her voice, which is attracting a great deal of attention throughout the country on the NBC network.

Those who sat in the audience could feel the effects of the colors as well as the effects of the music and the proof was ample that in the combination of color and music we have the true art of appealing to the soul and the human emotions and that through this combination startling psychic effects can be produced and the psychic centers of the human consciousness awakened in a shorter time than by any other means.

This color organ has required over a year's labor to plan and build, for nearly every part in it had to be made by hand, there being nothing in the open market that can be purchased for such a large and complete instrument as this master color organ. Several thousand feet of electric wires, many hundreds of minute electrical contacts, many hundreds of vibrating and properly tuned adjustments had to be made and practically every fundamental law of physics, electricity, magnetism, music, art, and harmony had to be employed in the creation and building of this superb instrument.

Undoubtedly, all of the musical magazines, as well as the art and scientific magazines, will speak of this color organ for it is an unusual and valuable contribution to their arts. The color organ will be demonstrated again when the Convention is held by our organization this coming summer. Therefore, there is one intensely interesting and profitable feature to which all of you may look forward in making your plans for next summer's vacation.

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